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Novel supramolecular biomaterials for piezoelectric applications

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Novel supramolecular biomaterials that mimic the structural peculiarities of living organisms and have significant pyro-, piezo- and ferroelectric properties have recently emerged because of the range of novel applications. One of these materials, diphenylalanine (FF) is one of the self-assembling peptides which have recently become a focus of intensive research in the field of nanomaterials because they can spontaneously form fascinating discrete and well-ordered structures: nano- and microtubes, nanospheres, nanofibrils, and hydrogels [1]. FF peptide tubes (PTs) possess unique biological and physical properties such as inherent biocompatibility, high aspect ratio and remarkably rigid structure [1]. Strong piezoelectricity found recently in FF adds a new important functionality useful for the development of sensors, actuators and micromechanical systems [2]. Piezoeffect was found to be sufficiently stable being strongly dependent on the chemical modifications and synthesis conditions [3]. Thus, biocompatible, lightweight and highly mechanically stable FF PTs are an attractive material for the fabrication of future generation of resonance biosensors [4], energy harvesting elements, and other devices.

In this work, we report the results of our recent studies on the growth and characterization of FF PTs by piezoelectric, pyroelectric and dielectric methods [5-7]. A method of growth of large (mm size!) microtubes consisting of individual FF nanotubes was developed [5] and thus the tubes could be transferred and mounted on structured substrates. Piezoelectric properties were then evaluated either by the resonance method or by quantitative Piezoresponse Force Microscopy (PFM). We show that the entire piezoelectric matrix of diphenylalanine peptide microtubes could be measured if the proper arrangement of the tubes is constructed [6]. Piezoelectric coefficients were sufficiently high and comparable to those of ZnO and $LiNbO_3$. Also a significant pyroelectric effect was found in FF mictotubes grown by this method [7]. Low temperature phase transitions were rigorously studied by dielectric spectroscopy. Several anomalies were found in the temperature range 100-350 K accompanied by the strong dielectric relaxation. Unusual behavior of the dielectric relaxation times observed in this work was attested to the relaxation of water molecules in FF PTs nanochannels. At low temperature two groups of water molecules coexist near the hydrophilic carboxyl groups and in the core of nanochannels having completely different dynamics leading to structural changes. A crucial role of nanoconfined water in emerging physical properties of FF peptide tubes will be discussed in this work.

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